

Shop Floor as a National Measurement Institute

Program Manager: Dennis A Swyt
Total FTE: 3.35
Total Funding: \$854,100

Goal

To develop the means to allow U.S. manufacturing firms to meet the global-market requirement for the “new traceability” by making task-specific measurements effectively and economically on the shop floor that:

- realize the international standard of length without dependence upon calibrations made by NIST or any other National Measurement Institute (NMI);
- use measurement uncertainty to describe the expected variability in the measurement result; and
- approach the highest level of accuracy technologically attainable, without development by NIST of the task-specific measurement services or capabilities themselves.

The program aims to develop, validate, and propose for standardization an array of non-task-specific techniques that would allow task-specific dimensional measurement, on parts in the manufacturing shop floor environment of a demonstrable uncertainty and traceability to the Systeme Internationale d’Unites (SI) unit of length without recourse to, or dependence on:

- (1) provision by NIST of a task-specific measurement service; or
- (2) development by NIST of a task-specific measurement capability; or
- (3) development for testing by NIST of a task-specific measurement methods.

Program Objectives

FY2001

Support direct and immediate realization of the SI unit of length on the shop floor by developing a simple robust refractometer for the measurement of the index of refraction in shop-floor environment.

Refractometry

Conduct study (including laboratory investigations, literature review, and industry interactions) to (1) assess promising refractometer technologies for measurement of local index of refraction and (2) define industry needs from large scale manufacture (such as aerospace) to small-scale manufacture (such as semiconductor) and publish at least one related paper.

FY2002

Support direct and immediate realization of the SI Unit of length on the shop floor by exploring or developing new technologies for multi-color and wavelength-sweeping interferometric measurement techniques that will improve the utility and accuracy of shop-floor interferometric measurements.

Multi-color Inteferometry

Conduct study (including laboratory investigations, literature review, and industry interactions) to (1) assess promising multi-color and wavelength-sweeping technologies for absolute distance interferometry and for measurement of global (path-integrated) refractive index and (2) define industry needs from large-scale manufacture (such as aerospace) to small-scale manufacture (such as semiconductor).

FY2002

Support achievement of NMI-type accuracy in shop-floor dimensional measurements by developing a high-precision dilatometer to provide state-of-the-art measurement of coefficients of thermal expansion.

Dilatometry

Design, assemble, test, and characterize a version-one displacement-interferometer-based 15 °C to 25 °C-range dilatometer and carry out test measurements on a set of long industrial length artifacts of different materials and geometries, including a 20-inch steel gage block, a 10-inch Cervit gage block, and a KOBA step gage.

FY2002

Identify and cooperate in industry measurement assurance programs, proficiency testing, and round robins that support the realization of the Shop-Floor-as-NMI paradigm for providing accuracy and traceability for the industry required task-specific measurements.

Accreditation

Produce a report that identifies existing and future accreditation-body-recognized procedures to allow the accreditor-satisfying assertion by an industry shop-floor practitioner that post-process dimensional measurements made on a manufactured part exhibit a stated measurement uncertainty and traceability directly to the SI unit of length rather than to task-specific dimensional standards calibrated by a National Measurement Institute.

FY2003

Support use of measurement uncertainty in shop-floor measurements to be used in marketplace decisions by developing methods for producing Guide to the Expression of Uncertainty in Measurement (GUM)-compliant statements of uncertainty for shop-floor measurements of manufactured parts.

Measurement Uncertainty

Generalize, validate, and demonstrate a Monte-Carlo-statistics-based technique for computational modeling of the uncertainty of shop floor Coordinate Measuring Machine (CMM) measurements of manufactured parts including one with determined kinematic error parameters and provision for future inclusion of the effects of thermal distortions due to time-varying and spatial-varying temperatures during the measurement process.

FY2003

Collaborate with individual manufacturing companies on co-development and testing in manufacturing environments of the concepts, methods, and technologies supporting the Shop-Floor-as-NMI paradigm.

Boeing Collaboration

Collaborate with Boeing Commercial Aircraft Company, including pursuit of a cooperative agreement, on the application of the Shop-Floor-as-NMI paradigm. Specifically, apply paradigm to qualification on the manufacturing shop floor of an absolute-distance-interferometer laser-tracker system to make demonstrably traceable measurements in production of commercial aircraft.

FY2004

Support achievement of NMI-Type accuracy in shop-floor dimensional measurements by developing realistic models, uncertainty estimates, and compensation techniques for the effects on post-process inspection of the thermal distortion of parts, gages, measuring machines and structures in typical manufacturing processes and environments.

Thermal Distortion Models

Develop, validate, and demonstrate on the NIST Fabrication Technology Division (FTD) shop floor a first-order simulation (involving Monte-Carlo statistical-ensemble and finite-element-analysis models) of the effect on measurement uncertainty of post-process measurement of a manufactured part. This will

include thermal distortion for a feasible combination of characteristics of part, measuring machine, and time-varying and spatial-varying temperatures representative of the manufacturing shop-floor environment.

FY2004

Support use of measurement uncertainty in shop-floor measurements to be used in marketplace decisions by developing models and simulations of use of measurement uncertainties in conjunction with design tolerances and actual part deviations in decisions on conformity of manufactured parts to specifications.

Decision Models

Produce a research-based technical report on the use of shop-floor measurements with uncertainties containing uncorrected systematic errors in accept or reject decisions of conformity of manufactured parts to specifications.

FY2004

Develop techniques that will allow practitioners in U.S. manufacturing industry to implement in standards-body-recognized ways the three elements of the Shop-Floor-as-NMI paradigm and then provide those techniques to standards committees.

Standardization Techniques

Produce a report that identifies existing and need-to-be-developed U.S. national standards to allow the standards-supported assertion by an industry shop-floor practitioner that post-process dimensional measurements made on a manufactured part exhibit GUM-based measurement uncertainty and traceability directly to the SI unit of length rather than to task-specific dimensional standards calibrated by a National Measurement Institute.

FY2004

Investigate and apply the extension of the Shop-Floor-as-NMI paradigm from length dimensional measurements to other quantities for which MEL and NIST have calibration services and traceability responsibilities.

Customer Needs

The spectrum of U.S. manufacturers, from aircraft and automobiles through microelectronics and computer disc-drives, face simultaneously three technological trends which together require them to make measurements on manufactured parts on the shop floor by manufacturing personnel with three characteristics that have historically only been associated with measurements made at National Measurement Institutes (NMIs) by professional metrologists.

First, shop-floor measurements in high-technology manufacturing now need to be of the highest metrological quality (i.e., accuracy) technologically attainable, a characteristic historically only of NMI's best measurements. The principal driver of manufacturer's needs to make the highest accuracy measurements technologically attainable lies in Moore's Law by which manufacturing tolerances tighten by a factor of three every decade and the accuracy of measurements needed to assure conformance to those tolerances, increasing at the same rate, run into scientific and technological limits.

Second, shop-floor measurements in manufacturing for the global market are being required by international product standards to satisfy new requirements for explicit traceability to the international unit of length, historically traceability only being associated with standards-laboratory standards. The principal driver of U.S. manufacturers' needs to satisfy this "new traceability" is a suite of new international standards to which they must conform to satisfy foreign customers.

Third, shop-floor measurements are beginning to be required to have associated with them a stated measurement uncertainty, again a characteristic until now only associated with standards-laboratory measurements. The need to associate measurement uncertainties with shop-floor measurements lies in the need to take uncertainty into account when determining whether a part as made conforms to the part as specified. The princi-

pal driver for taking measurement uncertainty into account is the business decision of whether a producer's product conforms to a customer's design specification, either because measurement uncertainty represents a substantial part of a tight tolerance or a customer requires that a producer conform to the suite of international product standards indicated above.

Technical Approach

The "Shop Floor as NMI" program aims to provide a basis for both satisfying U.S. industry needs for the "new traceability" and reducing the number of NIST-provided task-specific length measurement services in both relative and absolute terms. The program aims to develop validated non-task-specific methods by which industry may perform their own traceability-satisfying NMI-quality task-specific measurements of parts on the shop floor without recourse to NIST-provided calibrations or NIST-developed task-specific measurement capabilities or methods.

This scope of the program includes no development of task-specific measurement services, capabilities, or methods themselves. The non-task-specific methods and procedures are to be co-developed by NIST and industry in the NIST laboratory, including being tested on the shop floors of industrial partners.

The technical approach also includes developing and proposing these procedures and methods to key standards committees for formal adoption as standard practices. Relevant standard committees are the following subcommittees of the American Society of Mechanical Engineers Dimensional Metrology (B89) Committee: B89.1 - Length, B89.4 - Coordinate Measuring Technology, and B89.7 - Measurement Uncertainty. The final realization of this program will be a set of procedures and methods that addresses

how a shop-floor practitioner may realize, assert, and demonstrate from first principles the "new traceability" directly to the SI unit of length. In addition, throughout the proposed program, standards committees will also be used as focus groups for collaboration with industry on development of the standardized procedures and methods for making measurements and handling uncertainty under this new paradigm of "shop floor as NMI".

Standards Participation

- American Society of Mechanical Engineers B89.1 Length: This subcommittee's primary focus is to develop standards dealing with length such as: gage blocks, circular gages, measuring tapes, lasers, micrometers, calipers and thread wires. Modifications to these standards are imperative if this program is to succeed.
- American Society of Mechanical Engineers B89.4 Coordinate Measuring Technology: This standards subcommittee supports the needs of U.S. industry at a scale of one meter or larger, by developing standards which assess the uncertainty of measurements made by the family of coordinate measuring instruments. This subcommittee is presently developing standards that deal with coordinate measuring machines and optical coordinate measuring systems.
- American Society of Mechanical Engineers B89.7 Measurement Uncertainty: This subcommittee will be the primary driving force behind the adoption by U.S. industry of the concept of the Shop Floor as an NMI. The focus of this subcommittee is to develop voluntary product standards dealing with statements of measurement uncertainty, including an element of modern definition of traceability.